NUMERICAL STUDIES OF ACOUSTIC PROPAGATION IN SHALLOW WATER

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Award: N00014-96-1-0790, Category: Shallow-Water Acoustics

LONG TERM GOALS

To develop ``exact" numerical methods that can be used to study the propagation of acoustic energy in shallow water. Exact in this contexts means that the methods place no restrictions on the underlying physics of the environment.

OBJECTIVES

To develop new, and enhance existing, numerical methods; to establish the accuracy, robustness, flexibility, and tractability of these methods; and to apply these methods to meaningful practical problems.

APPROACH

: We have focused our attention on the development and use of the finite-difference time-domain (FDTD) method. This time-domain technique, which is flexible, robust, and simple to implement, has previously been used by the electromagnetics community to solve a wide range of problems. However, the FDTD method has not been widely used by the acoustics community and its ability to accurately solve many of the problems related to propagation in a shallow water environment is the subject of continuing research.

WORK COMPLETED

FDTD algorithms were developed; the corresponding computer programs were written; and the information related to our experiences was disseminated via journal publications and conference presentations.

RESULTS

Numerical methods, such as the FDTD method, model a finite physical space. In order to simulate the behavior of an unbounded space, the computation domain must be terminated with a suitable ``absorbing boundary condition" (ABC). We developed an ABC for elastic material that is arguably superior to all others that previously have been

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 1997**	2. REPORT TYPE	3. DATES COVERED **00-00-1997 to 00-00-1997**
4. TITLE AND SUBTITLE **Numerical Studies of Acoustic Propagation in Shallow Water**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Washington State University,School of Electrical Engineering & Computer Science,Pullman,WA,99164**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**3**	

reported [JASA, 100(5):3061--3069, 1996]. The standard FDTD scheme approximates hard and pressure-release boundaries (such as pertain at an impenetrable bottom or at the air-sea interface) using a staircase representation. We presented a technique to improve the representation of these types of boundaries [IEEE Trans. Microwave Theory Tech., 44(10):1728--1733, 1996]. Along the same lines, we performed careful FDTD simulations of propagation in wedge structures to establish guidelines for acceptable cell sizes using staircased boundaries [to appear in IEEE Trans. Antennas Propagat., Dec. 1997]. We developed a new technique for introducing fields into FDTD computational grids. This technique permits the source of fields to be ``transparent'' so that the source itself does not interfere with the propagation of fields [to appear in JASA]. We have firmly established the ability of the FDTD method to model accurately the scattering from randomly rough pressure-release surfaces. This was previously done for infinite surfaces using a Monte Carlo technique and recently for single a 1 ``benchmark'' rough surface [to appear in JASA]. Another ABC was developed for terminating acoustic grids. This ABC is a modified version of one that has been in widespread use for several years. To use the modified version requires only minor changes to existing computer codes and yet the modified version is significantly better than the original ABC (i.e., it much better mimics the behavior of an infinite grid and hence helps ensure the accuracy of a simulation) [submitted to JASA].

Finally, given our need to view the propagation of fields in the time domain, we developed a simple rendering scheme that could be used to ``instrument'' numerical modeling code [IEEE Antennas & Propagat. Mag., 38(6):7--17, 1996].

Additionally, our work has been reported in two invited talks and four conference presentations. These presentations have dealt with various aspects of our experiences with the FDTD method including our initial work using the FDTD method to find the acoustic energy scattered from randomly rough fluid-fluid and fluid-elastic interfaces.

IMPACT/APPLICATIONS

Accurate and flexible numeric methods give one the ability to conduct any number of experiments without having to resort to actual field experiments, i.e., the experiment is conducted in the computer. Although numerical methods will never supplant field experiments, numerical methods (when used within their ``region of validity'') do provide an extremely cost-effective means of conducting controlled experiments.

TRANSITIONS

Much of the knowledge we have gained has been disseminated via publications and conference publications. Additional material has been made available via the Web (please refer to http://www.eecs.wsu.edu/ ~ schneidj and the associated links).

RELATED PROJECTS

This work is related to research being conducted in both high-frequency acoustics and long-range propagation. Numerical models, such as the FDTD method, can be used to predict the fields scattered from small objects under short-wavelength insonification or the propagation of long-wavelength signals over limited regions of the ocean.

Additionally, this work is related to the work being conducted by several other ONR-sponsored researchers including Shira Broschat, Eric Thorsos, and Ralph Stephen.

REFERENCES

Please refer to narrative above for references related to this effort.